Savannah River Site
Solid Waste Management Department
Consolidated Incinerator Facility
Operator Training Program

CONSOLIDATED INCINERATOR FACILITY (CIF) INCINERATION OVERVIEW (U)

Study Guide

ZIOITX93

Revision 01

____
Facility Manager / Date

____
Engineering / Date

____
Training Manager / Date

FOR TRAINING USE ONLY

The uncontrolled information contained in these training materials is FOR TRAINING USE ONLY. In no way should it be interpreted that the material contained herein may be substituted for facility procedures. Where copies of procedures are given, they are intended as examples and information only, and the latest revision of the material in question should be obtained for actual use. If you have any questions, contact your supervisor.

REVISION LOG

REV.	AFFECTED SECTION(S)	SUMMARY OF CHANGE
01	All	Formatting changes; revisions to objective levels and material revisions

TABLE OF CONTENTS

REFERENCES

1. Vavruska, John S., *Incineration Systems*, 1993 Incineration Conference, Knoxville, Tennessee

2. Steven DeCicco, *Combustion Heat and Mass Balances,* 1993 Incineration Conference, Knoxville, Tennessee

3. Steverson, E. Malone, *Offgas Treatment*, 1993 Incineration Conference, Knoxville, Tennessee

4. Design Engineering Training Course Number 7014, *Incineration Technology*, Rev. 0, November 1994

5. Elliott, Thomas C., *Standard Handbook of Powerplant Engineering*, 1989

6. Solid Waste Management Department Course Number ZIOITX25.01*, Incineration System (RK, SCC, BMS*), Rev 1

7. ASME QHO-1-1994, *Standard for the Qualification and Certification of Hazardous Waste Incinerator Operators*, 1994

LIST OF FIGURES

LIST OF TABLES

LEARNING OBJECTIVES

TERMINAL OBJECTIVE

1.0 Given course of instruction and applicable procedures and reference materials, **DEMONSTRATE** understanding of incineration principles through safe and efficient control of the Consolidated Incinerator Facility processes.

ENABLING LEARNING OBJECTIVES

1.01 **STATE** the purpose of an incinerator.

1.02 **IDENTIFY** the ideal characteristics of an incineration process to include the following portions:

a. Incinerator

b. Offgas

c. Ash

1.03 **LIST** the safety factors to be considered associated with the incineration process.

1.04 **IDENTIFY** the criteria used in selection of the Rotary Kiln Incinerator at CIF.

1.05 **DESCRIBE** the features, construction, and operating characteristics of the rotary kiln incinerator type to include:

a. Tumbling action

b. Kiln sealing

c. Secondary combustion

d. Operating temperature range

e. Excess air requirements

f. Acid gas neutralization

LEARNING OBJECTIVES (Cont.)

1.06 **DESCRIBE** the components found on incinerators to include the purpose, design considerations and construction of the following:

a. Rotary Kiln
b. Waste Feed System
c. Combustion Air Supply
d. Auxiliary Heat Supply
e. Ash Removal System
f. Secondary Combustion Chamber
g. Process Instrumentation and Control

1.07 **DESCRIBE** the advantages and disadvantages associated with the rotary kiln incinerator.

1.08 **STATE** the purpose of incinerator offgas treatment.

1.09 **EXPLAIN** the processing of incinerator offgas to include the components, types of contaminants and the required methods of conditioning for the following:

a. Halides (chlorine, fluorine, iodine and bromine)
b. Sulfur
c. Nitrogen
d. Inert materials
e. Metals
f. Radioisotopes
g. Plastic (PVCs)

1.10 **DEFINE** the categories of offgas systems to include:

a. Wet
b. Dry
c. Semi-dry/Hybrid

LEARNING OBJECTIVES (Cont.)

1.11 **DESCRIBE** the major components of offgas systems including the purpose, design considerations and construction of the following:

a. Quencher
b. Heat exchanger
c. Scrubber
d. Cyclone separators
e. HEPA filters

1.12 Given the appropriate drawing or block diagram, **LABEL** the major components of a wet offgas system to include the following:

a. Quencher
b. Scrubber
c. Separator
d. Demister
e. Reheater
f. Induced draft fans
g. Stack

1.13 **DESCRIBE** the interrelationships of the following support systems to incinerator operation to include the effects on incinerator operation due to a loss of the system.

a. Air
b. Service Water
c. Nitrogen
d. RK and SCC Fuel Oil
e. Propane
f. Forced Draft and Purge Air
g. Fire Protection
h. Tank Farm Support

LEARNING OBJECTIVES (Cont.)

1.14 **DESCRIBE** the interrelationships of the following electrical systems to incinerator operation to include the effects on incinerator operation due to a loss of the system.

a. Electrical Distribution
b. Heat Tracing
c. Standby Diesel Generator
d. Diesel Fuel Oil

1.15 **DESCRIBE** the interrelationships of the following process systems to incinerator operation to include the effects on incinerator operation due to a loss of the system.

a. Incinerator
b. Offgas
c. Solid Waste
d. Ash Handling
e. Liquid Waste

1.16 **DESCRIBE** the interrelationships of the following integrated systems to incinerator operation to include the effects on incinerator operation due to a loss of the system.

a. DCS
b. BMS

1.17 Given applicable references and a scenario with operating parameters for incinerator fuels and wastes, **DETERMINE** if the values are credible and within design limits for the following fuels and wastes:

a. Solid Waste
b. Liquid Waste
c. Aqueous Waste
d. Fuel Oil
e. Radioactive Organic Waste (ROW)

INTRODUCTION TO INCINERATION PROCESSES

Introduction

Combustion and incineration are very closely related terms. While combustion deals with the chemical aspects of oxidizing organic materials, incineration is the process of burning waste materials to ashes. Combustion air, fuel, temperature and combustion gas retention time are all controlled within the incinerator to achieve the following:

- minimal carbon residue in the ash
- minimal traces of smoke and organic material in the combustion gas
- minimal release of pollutants to the atmosphere
- conformance with established federal, state and local regulatory criteria

There are many different methods and technologies used for incineration. This course will describe the technology used at the Consolidated Incinerator Facility (CIF).

Incinerator Purpose

1.01	**STATE** the purpose of an incinerator.

An incinerator is a vessel or enclosure where a combustion process occurs and is used to thermally reduce the toxicity or destroy a volume of material. The primary function of the incinerator is to convert the organics in the waste streams to carbon dioxide (CO_2) and water (H_20) by reaction with the oxygen present in the combustion air fed to the incinerator. Routinely, incineration is used to reduce or destroy volumes of waste and hazardous materials. Incinerators are commonly used to destroy municipal waste (garbage), medical waste, hazardous waste from chemical processing, low level nuclear waste, and industrial byproducts.

Incineration has been a viable technology for waste reduction since the 1940's. Since 1981, stringent regulatory requirements have been placed upon incinerator operators and customers. Because of these requirements, incineration processes and emissions need to be monitored and controlled to ensure that the systems and byproducts do not pose a threat to human health or the environment.

Ideal Characteristics of an Incineration Process

1.02	**IDENTIFY** the ideal characteristics of an incineration process to include the following portions: a. Incinerator b. Offgas c. Ash

There are many desirable characteristics an incinerator should have in terms of operability and performance. The characteristics can be classified as pertaining to one or more of the following:

- mechanical operation of incinerator combustion chamber(s)
- chemical characteristics of the offgas generated by combustion
- physical and chemical characteristics of the ash (residue) generated

Figure 1, *Characteristics of an Ideal Incinerator*, shows desirable characteristics according to the classifications.

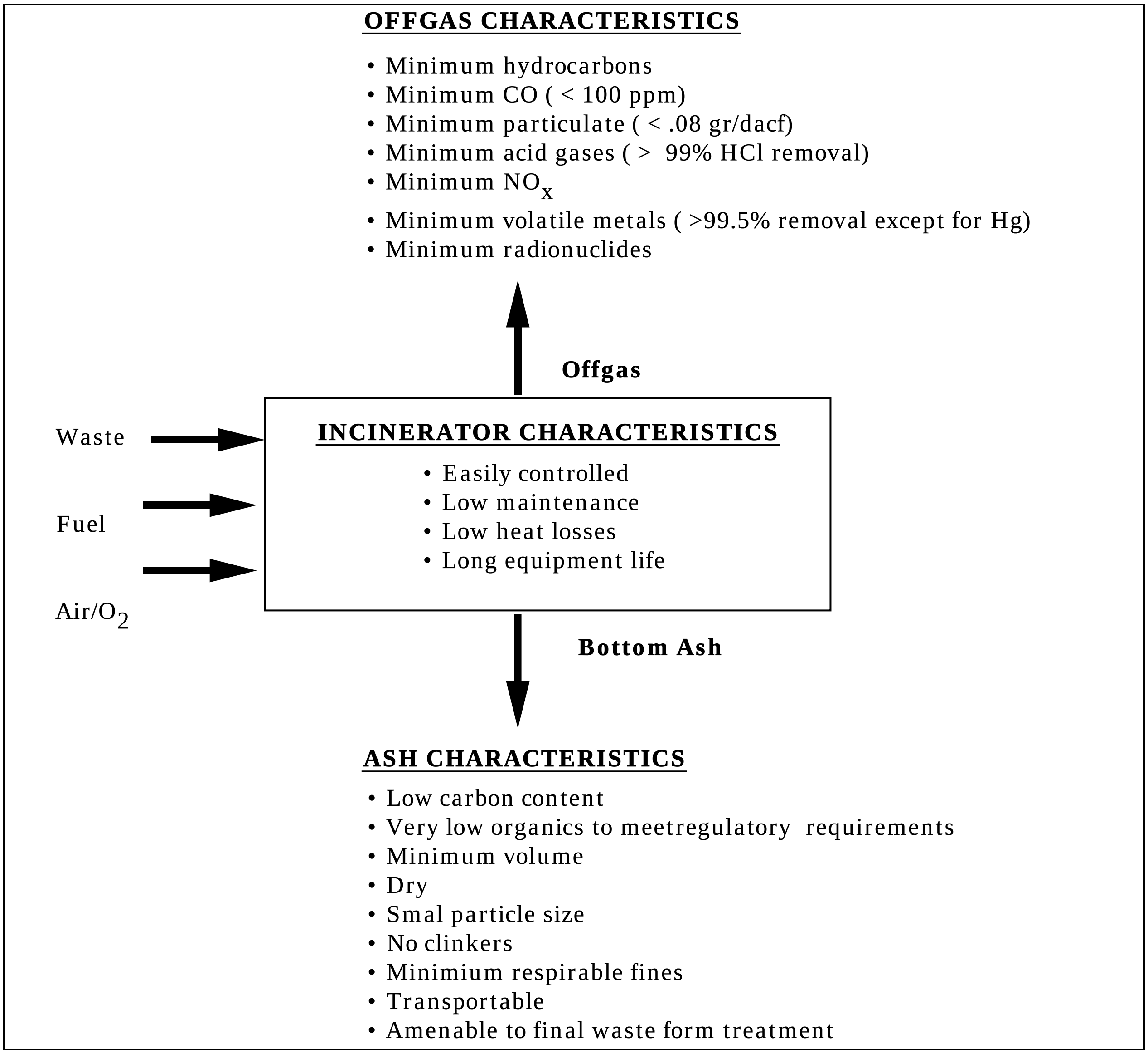

Figure 1, Characteristics of an Ideal Incinerator

As seen in the figure, first the incinerator must be easy to operate. This includes the combustion process, the waste feed and the ash withdrawal mechanisms. The ease of operation should apply to the ability to control the combustion process so that the temperatures, oxygen concentrations, fuel to air ratios, residence times and offgas flow rates can be maintained at desired levels. Additionally, the system should require minimal maintenance, have a long usable life and avoid excessive heat loss to the environment.

Because incineration is a combustion or high temperature process, the primary function of the incinerator is to convert the organics in the waste streams to CO_2 and waste by reaction with the oxygen present in the combustion air fed to the incinerator. Therefore the only emissions we would like to see from the incinerator are CO_2, water, nitrogen and excess oxygen. We would like to minimize the formation of carbon monoxide (CO) and nitrogen oxides (NOx), to destroy a high degree of hydrocarbons and to minimize the entrainment and physical carryover of particulate and residuals. We also want to prevent the formation and carryover of acid gases, metals and radionuclides in the offgas.

The quality of the solid residue (ash) produced by incineration determines the ultimate disposition as well as the acceptability of the incinerator itself. The ash produced should be a low volume, free flowing with few or no clinkers so that withdrawal is a straightforward process. The carbon content should be low and the residue chemistry should be such that the residue may be disposed of directly or, with further treatment, may be immobilized to produce an acceptable final waste form.

Safety

1.03	**LIST** the safety factors to be considered associated with the incineration process.

The primary safety concern of an incinerator or incineration process has to do with the temperatures required for incineration of the waste streams. Surfaces of the incinerator (the RK shell) and certain auxiliaries and support systems will not only be hot to the touch, but they will also serve to raise the surrounding ambient temperatures to levels that range from uncomfortable to those having a potential for creating heat stressful situations (at CIF, operators may be required to conduct activities on or around forced draft fans, the auxiliary diesel drive, the reduction gears, etc.). Personnel should always exercise care around the shell surface of the incinerator. In the unlikely event an operator would be required or need to place extremities on or near the shell, heavy gloves should be worn. The same precaution applies when manipulating atomizing steam or fuel valves.

Noise is also a factor to consider during incinerator operation. Hearing protection should be worn at all times in the vicinity of operating incinerators or auxiliaries. At CIF, hearing protection is required at all times in the incinerator and offgas areas, primarily because of the high pressure steam to the offgas scrubber.

Many of the support systems use rotating equipment (pumps, fans, blowers, etc.) for process operations. Personnel should ensure that they do not wear chains, necklaces or loose articles of clothing in the vicinity of rotating equipment.

Many of the fuels used for incineration are not only chemically toxic, but they may present other hazards if they are spilled or leak. Personnel should take appropriate measures in dealing with spills and leaks of waste materials. Many of the corrective measures are addressed through the cognizant procedures but operators should always avoid walking through barricades or around areas where spills or leaks have occurred.

Operators are routinely called upon to physically lift materials. Proper lifting techniques and protective gear should be used when performing any lifting.

There are numerous electrically powered components throughout the incineration facility. Proper electrical safety precautions are documented and proceduralized and should be adhered to any time that electrical equipment is being operated or aligned.

High pressure systems, such as the Steam System, are used to support incinerator operation. Operators should exercise caution any time they are working with high pressures to ensure that they are not injured by inadvertent leaks, overpressurization, or relieving systems to the atmosphere.

The areas around the incinerator have painted concrete surfaces. In the event of a leaks or a spill, the surfaces will be slippery. Personnel should exercise caution or avoid walking across slippery surfaces.

Summary

- The primary function of the incinerator is to convert organics in the waste streams to carbon dioxide (CO) and water by reaction with oxygen in combustion air
- There are several characteristics that ideal incinerators have dealing with operability and waste processing
- Incinerator safe operations requires operating personnel to be aware of both incinerator operating fundamentals and fuel and waste characteristics

Review

1) Complete the following table to identify the ideal characteristics of an incinerator

Section	Ideal Characteristics	Reason(s)
Incinerator	Easily controlled	
	Low maintenance	
	Low heat losses	
	Long equipment life	
Offgas	Minimum hydrocarbons	
	Minimum CO	
	Minimum particulate	
	Minimum acid gases	
	Minimum NOx	
	Minimum volatile metals	
	Minimum radionuclides	
Ash	Low carbon content	
	Minimum volume	
	No clinkers	
	Minimum respirable fines	
	Transportable	
	Amenable to final waste form treatment	

2) Identify three safety factors and the reasons associated with incineration.

ROTARY KILN INCINERATION

Introduction

In order for an incinerator to perform its function, it should have many components and features that work in conjunction with the others. Proper design and selection of incinerator types, features and subsystems is primarily dependent upon the types of waste streams that are to be processed. The chemical and physical characteristics of the wastes will also have an impact on the performance of each of the system components.

Incinerator Technology Selection Criteria

1.04	**IDENTIFY** the criteria used in selection of the Rotary Kiln Incinerator at CIF.

Selection of an incinerator type and the effective components to be used in the design is a complex decision. Some of the guidelines that are used during the selection process are:

- Waste feed acceptance criteria - waste must be thoroughly characterized and the waste streams should be identified before design and construction begin. Physical characterisitcs such as the form(s) of the waste, handling characteristics, and container types all influence the selection process. Chemical characteristics such as water, organics, inerts, salts, halogens and heavy metal content also have effects on the design of the incinerator as well as the air pollution control system (offgas conditioning).
- Process effectiveness - performance or effectiveness can be based upon actual experience with similar waste treatment systems. Criteria may be based upon the ability of a system to destroy organic materials in the waste, quality of ash or residue produced and whether is it suitable for treatment into a final form.
- Offgas composition - control of the nature and quantity of the offgas is the design basis for an air pollution system. Thermal treatment technologies that can minimize the generation of particulate, metals, NOx, SOx, organics and CO should be considered.
- Secondary wastes - secondary wastes should be minimized to have the smallest effect on the final disposal capacity. Amenability of solid waste disposal in landfills is preferable to further treatment of residue and ash.
- ALARA concerns - operator exposure to toxins, chemical or radioactive contamination should be minimized. Exposure considerations should dictate that the system will require minimal personnel access into process internals, minimize buildup of waste materials in any phase of the process

The design process must also include performance of heat and mass balance equations. Heat and mass balance equations are performed for the following reasons:

- Determine the size of the unit based upon the waste feed rate and composition
- Determine waste feed rates for a given heat release rate and combustion gas flow rate
- Determine the effect(s) on a given process or unit for a change in waste feed characterisitics

Heat and mass balance account for the chemical properties of the waste streams, system boundaries, operational modes, control operation, operating parameters, and emissions. Heat and mass balance equations provide information regarding waste feed rates, heat release rates, gas flows, operating temperatures and pressures, air flows, gas concentrations, equipment sizing, etc..

Design of the incineration system must also consider material properties of the equipment. Once a type of process is selected, the materials chosen to fabricate the equipment must have the ability to withstand stress, accomodate mass, temperature and flow requirements, and effectively process all input and output streams. For instance, various types of steels have different conductive heat transfer values. This is an important part of the selection process to ensure that the materials chosen will withstand design incinerator temperatures. Figure 2, *Thermal Conductivity of Some Commonly Used Steels*, shows the different values of thermal conductivity, k, for the various types of materials considered in the design criteria selection process.

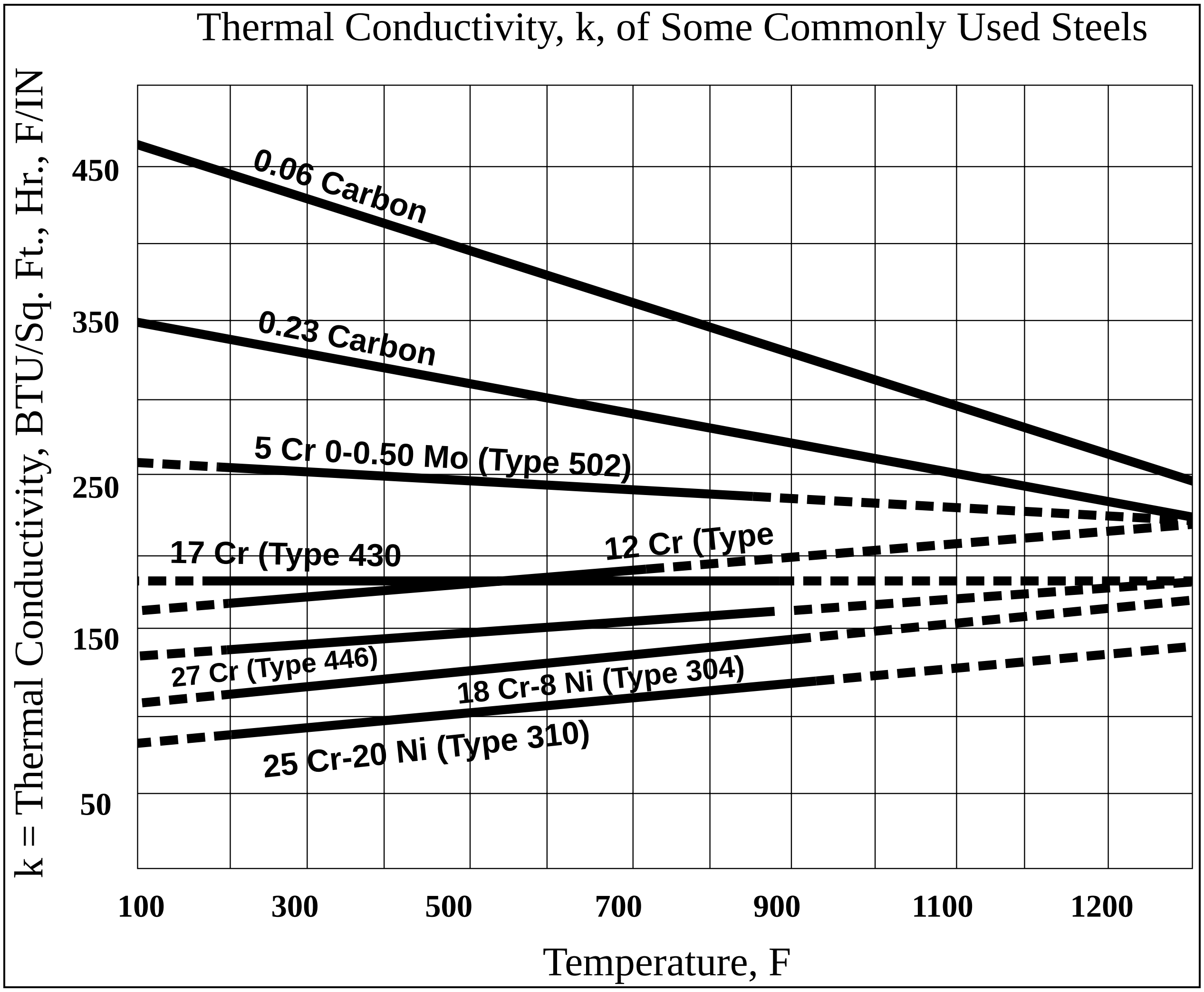

Figure 2, Thermal Conductivity of Some Commonly Used Steels

Rotary Kiln Incinerator Type

1.05	**DESCRIBE** the features, construction, and operating characteristics of the rotary kiln incinerator type to include: a. Tumbling action b. Kiln sealing c. Secondary combustion d. Operating temperature range e. Excess air requirements f. Acid gas neutralization

The rotary kiln incinerator type was chosen for use at the CIF based upon design considerations for the types and volumes of waste to be processed. Rotary kilns allow a greater flexibility in the types of waste feeds than some other types of incinerators. The rotary kiln at CIF allows the facility to process wastes in three physical states - liquids, solids and sludges. Figure 3, *Rotary Kiln Incinerator*, shows a typical unit.

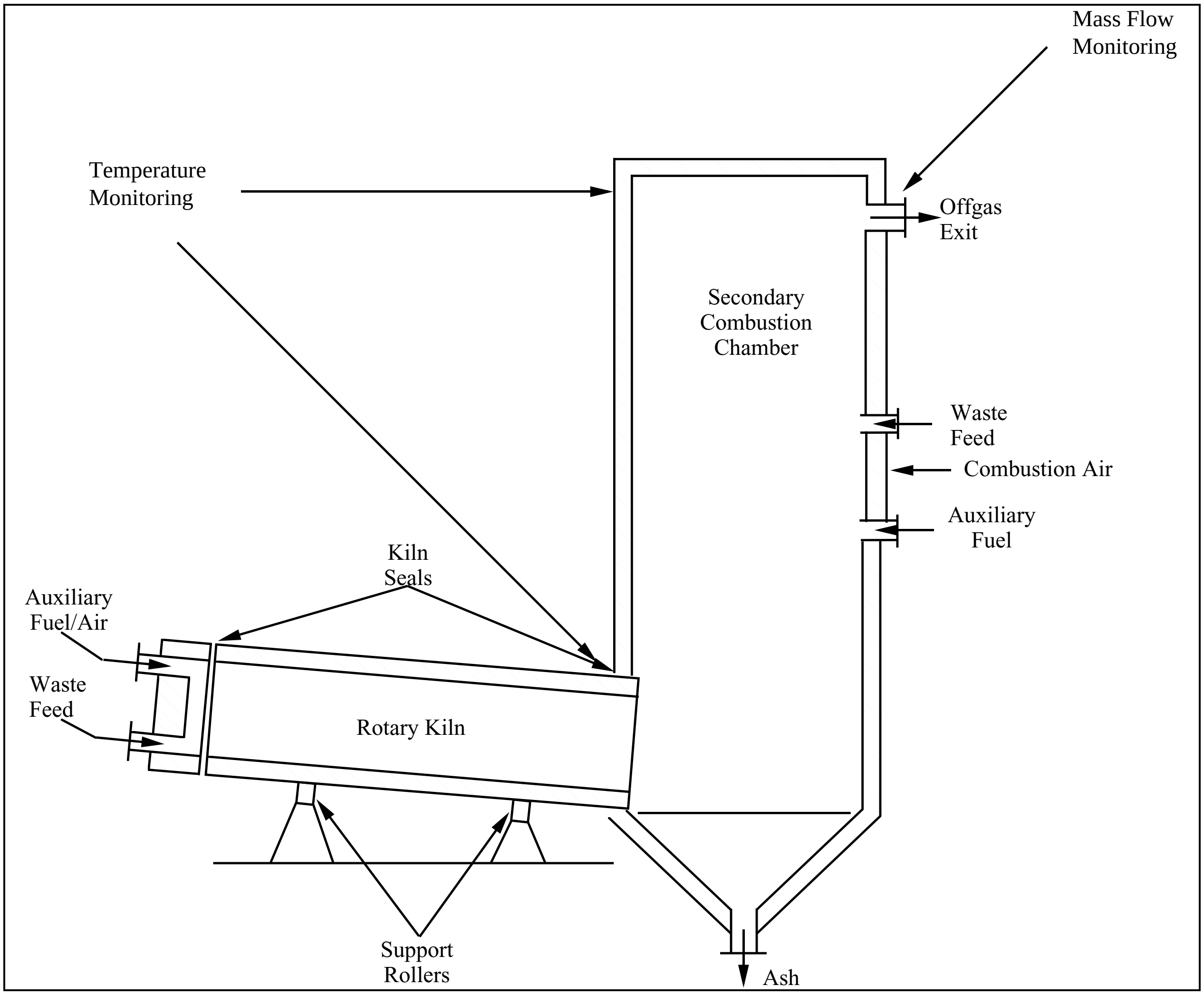

Figure 3, Rotary Kiln Incinerator

Rotary kilns are a well demonstrated technology that have been used for many years in the processing industry. The action of a rotary kiln is to contact combustion air with a tumbling bed of solids at a high temperature. Because the kiln is slightly inclined, the waste materials injected at the feed end slowly advance down the length of the assembly. The tumbling solids continuously expose fresh surfaces for combustion or vaporization. The solid residue remaining at the end of the kiln drops by gravity into the ash handling equipment under the discharge end of the kiln. Typically, rotary kilns have a 3 to 1 ratio of length to diameter. This ensures sufficient residence time of the solid waste incinerated in the kiln.

The rotating section of the kiln is supported on rollers with larger units requiring ring and pinion drives and smaller units driven by friction through the support rollers.

Rotary kilns are provided with seals to prevent the escape of combustion gases, excess heat and contaminants and to prevent the in-leakage of air. Kiln sealing can be a cause of concern because of the friction from the rotating action and generated heat so a sliding contact type of seal with malleable facing and seating surfaces is normally used. Kiln sealing can also be a concern because of a phenomenon known as "puffing". Puffing occurs when smoke comes out of the seals at the interface between the rotating and stationary sections of the kiln. The smoke may contain contaminants that could be released to the environment.

When hazardous waste is burned in rotary kilns with excess air requirements, a secondary combustion chamber (sometimes referred to as an afterburner) may be used. The secondary chamber provides additional gas residence time to ensure complete combustion of particulate carryover and combustible gases. Gas residence time in the chamber is normally 1 to 3 seconds, dependent upon the air flow through the kiln.

The CIF RK operates at temperatures between 1450°F to 1840°F. The temperature ranges are dependent upon the fuels, wastes, refractory and vessel materials, excess air requirements, emissions requirements and the types of firing equipment used.

Most high temperature RK units operate with excess combustion air between 25 to 100%. CIF excess air to the RK has been changed to operate in the range of 15 to 20%. The operational ranges for excess air are dependent upon the temperature, fuel characteristics, pressures required in the combustion vessel, and the type of firing equipment used.

When burning chlorinated or sulfonated hydrocarbon waste (such as shredded PVCs at CIF), an excessive amount of acid gases may be generated. Some neutralization of the acids is possible by adding an alkaline additive in granular form through the solid waste injection equipment.

Incinerator System Components

1.06	**DESCRIBE** the components found on incinerators to include the purpose, design considerations and construction of the following: a. Rotary Kiln b. Waste Feed System c. Combustion Air Supply d. Auxiliary Heat Supply e. Ash Removal System f. Secondary Combustion Chamber g. Process Instrumentation and Control

An incinerator requires specific equipment to perform the combustion and incineration of fuels and wastes. The type of equipment found in most incinerator units is described as follows:

Rotary Kiln

The RK is the chamber where primary combustion of fuels and wastes occurs. The RK structure or vessel receives the wastes and contains the gases produced during the combustion process. Physical and chemical conditions within the chamber are severe with temperatures usually in the range of 1450°F to 1840°F. The atmosphere in the chamber can either be starved or excess air. In addition, acid gases created from combustion of waste containing chlorides and sulfur are potentially highly corrosive. This makes the selection of materials for use in construction very challenging.

Most incinerators consist of a steel shell lined with one or more layers of fire brick (refractory). The steel shell forms the structural support for the incinerator and the containment for combustion gases. The refractory provides resistance to the high temperatures inside the chamber. The refractory thickness depends on the desired outside shell temperature, allowable surface heat losses, chamber temperature and physical property of the chosen type of refractory. Refractories are also chosen based upon heat balance equations to determine the amount of heat transfer that is desired to occur between the refractory, lining and the shell. Because of the compressive factors of the chosen refractory type at CIF, there is no insulation between the refractory and the shell in the rotating section of the kiln.

The chamber is physically sized based upon the desired heat release rate or thermal capacity. The thermal capacity is the product of the average heating value of the waste streams and the waste feed rate. Thermal capacity is also determined by the size of the waste and fuel burners or nozzles. Another important parameter to consider when sizing the chamber is the heat release rate of the waste streams. The additional heat release rate of the supplemental fuels must also be accounted for when sizing the chamber.

Waste Feed System

Waste feed systems introduce the waste streams into the incineration process in a controlled manner. Waste feed systems are designed for very specific physical characteristics associated with the constituents of the waste streams. The combustion process and the offgas treatment system will operate more smoothly if waste is fed continuously with minimal transients in the flow rates.

Waste feed system design considerations must account for both physical and chemical properties of the waste streams. Some of the physical characteristics of concern are the physical form (solids, liquids, sludges, and gases), handling properties (viscosity, stability, reactivity, flammability, volatility, termperature) and the container types (boxes, drums, tasnks, cylinders, lab packs). Some of the chemical characterisitcs to consider are as follows:

- Water - water is endothermic (it absorbs heat); increasing the amount of water fed to the incinerator decreases the combustion temperature, increases auxiliary fuel feed rate, and increases the saturation temperature of quenched combustion gas
- Organics - exothermic (release heat); increasing the amount of organics fed to the incineratyor decreases the auxiliary fuel feed rate. If organics feed increwase is not offset by a decrease of auxiliary fuel feed, the combustion temperatures will increase, combustion air requirements will increase and subsequently increase the amount of combustion gases produced
- Inerts - ash, silica and soils have an endothermic effect; increasing inerts decreases the combustion temperature, increases auxiliary fuel feed rate and increwases heat carried out of system (as hot ash)
- Salts - incinerator ash typically has high concentrations of alkali metals and salts such as NaCl, Na_2O, $CaCl_2$, and Na_2SO_4; these matals have low meltying points and can easily form slag on refractory and incinerator surfaces; also, some particulate will be carryied over in the combustion gases and offgas as the vapors condense
- Halogens - organic halides combine with hydrogen to form acid gases; as concentration increases, neutralizing agent (NaOH) use increases, production of salts and dissolved solids increases and blowdown waste volume increases
- Heavy metals - metals present in ash can cause ash residue to be classified as hazrdous; metals in the vapors and offgas will condense in scrubber but can render the blowdown hazardous

Liquid wastes are usually introduced into the chamber through dedicated high intensity burners or spray nozzles. Fumes and generated waste gases are usually introduced through dedicated burners or manifolds that mix the gas with air. Solid wastes are fed into the incinerator in batches in a packaged form or as a shredded material.

The waste burners are long flame, gun-type burner designed for incineration of high heating value waste. They are capable of passing particulate up to 1/16 inch in diameter and have turndown ratios. A turndown ratio is nothing more than the ability to decrease flow through the burner, from maximum to minimum, without the flame becoming unstable. In the case of the Blended Waste Burner at CIF, the maximum flow through the burner is 385 lb/hr with a minimum flow of 96 lb/hr which equates to a turndown ratio of 4:1. Steam is provided to the burners for cooling and atomization.

Combustion Air

Because oxygen is required for combustion, a reliable means of introducing oxygen at a controlled rate is essential. Air is normally used as a source of oxygen.

Air is supplied and removed by forced draft fans upstream with induced draft fans downstream of the offgas system. This arrangement provides the motive force for mixing of combustible materials with oxygen as well as the transport of the combustion gases through the system. The forced draft fans supply low pressure air through burners and nozzles that overcome the frictional losses in the air ducting as well as any resistance to flow in the burners. The induced draft fans pull air through the emissions filtering systems (Offgas). Combustion air is supplied at a variety of physical locations on the incinerator.

Auxiliary Fuel/Heat Supply

Most waste streams have enough heating value to sustain the combustion process but they do not have enough to bring the incinerator up to operating temperatures without sustaining refractory damage or requiring excessive flows. For this reason, a high heating value fuel is used to heat up the incinerator to operating temperatures at a controlled rate. The fuels are also used to maintain stability and provide reliable cycling for process parameter transients.

Auxiliary fuels are usually fed to the incinerator through a dedicated burner with it's own combustion air supply. The most common types of fuels used are natural gas, propane and fuel oil. Selection of a particular fuel or fuels is based upon design and economical considerations.

The auxiliary fuels are routinely atomized with medium to high pressure steam or air. Atomization is used to ensure that there is sufficient surafce area contact between the fuel and combustion air to ensure complete combustion. If the atomizing fluid supply flow or pressure were reduced or lost, the effects on the fuel flow to the incinerator combustion chamber could range from pluggage of the burner, damage to the burner, flow variations, smoking in the chamber, incomplete combustion or loss of flame.

Ash Removal System

An ash removal system is supplied to remove residual and particulate matter from the burning of solids material in the incinerator. Depending upon the type of incinerator and the characteristics of the solid waste streams, withdrawal of the ash residue can be continuous, semi-continuous or batch type. Some facilities are designed for ash withdrawal by personnel entry into the combustion chamber after a cooldown period. This method is impractical and poses severe personal health risks when processing waste streams that are radioactively or chemically contaminated. At CIF, an automatic backhoe arrangement is used for ease of operation, to minimize operator exposure to excessive temperatures and for ALARA concerns.

For continuous or semi-continuous operation, ash can be removed by gravity feed into a wet hopper or receiver by a mechanical conveyor or pneumatic transport. Selection of the methods involves consideration of the solid waste feed rate, physical properties of the ash, tolerance of flyash in the offgas, space constraints, and ALARA issues.

One of the major safety concerns associated with the CIF ash removal systems is maintaining the water seal between the RK and the receiving tank. The water level in the receiving tank must be maintained at a predetermined level in the chute to prevent high temperature exposure to the chute materials (the flange gasket in particular) and the potential for evaporating the water in the receiving tank.

Secondary Combustion Chamber

Few, if any, primary combustion chambers alone can achieve complete or adequate destruction of a waste stream's principle organic hazardous constituents (POHCs) or products of incomplete combustion (PICs). It is the purpose of the secondary combustion chamber to complete the combustion process or completely destroying the organics and residuals in the combustion gases generated from the primary combustion chamber.

NOTE	During PTB, measurements of the POHCs was performed to determine offgas and incinerator efficiency. Several of the chemical drums containing the materials burned during the PTB evolution (e.g. toluene, benzene) were labeled as POHCs.

Secondary combustion chamber design is based upon the requirement for gases to remain in the chamber long enough and have the proper flow characteristics to ensure there is adequate residence time and thorough mixing to ensure complete combustion. That is why they are constructed with the length-to diameter (L/D) ratio being the critical consideration. The various L/D ratios have different residence time and turbulence characteristics. Ideally, we would like to have both sufficient residence time and adequate turbulence to ensure that all of the gas molecules are well mixed and remain in the chamber long enough so they are completely burned. The decision as to the type of geometry of the chamber is dependent upon the types of waste streams and economical considerations.

Process Instrumentation and Control

Instruments and controls are used to ensure the safe and efficient operation of the incinerator and support systems. Instrumentation critical to the safe and efficient operation of the incinerator usually includes monitoring of the following process parameters:

- chamber temperature - maintained and adjusted by control of waste feed and auxiliary fuel flow rates
- chamber pressure - controlled at slightly less than atmospheric pressure by fan dampers or variable speed induced draft fans
- combustion air flow - modulated for feed and fuel transients and chamber pressures
- fuel flow - modulated for waste and temperature adjustment
- waste flow - adjusted for chamber temperature or fuel flow
- oxygen and CO concentrations in the offgas - adjusted by varying combustion air flow rate in response to waste and fuel transients
- flame safeguards - critical for the safe operation of the burners, fans and blowers

Rotary Kiln Advantages and Disadvantages

1.07	**DESCRIBE** the advantages and disadvantages associated with the rotary kiln incinerator.

As previously mentioned, each incinerator type has inherent advantages and disadvantages. The rotary kiln type of incinerator characteristics are shown in Table 1, *Comparison of Rotary Kiln Advantages and Disadvantages*.

ADVANTAGE	DISADVANTAGE
Able to incinerate a wide variety of waste streams	Relatively high particulate carryover in the gas stream
Many types of feed mechanisms available	Separate afterburner required for the destruction of volatiles
Provision of high turbulence and effective contact with combustion air in the kiln	Requires high amount of excess air (usually 100 to 150%)
Easy control of waste residence time in kiln	Little or no ability to control conditions along the length of the kiln
Minimal waste reprocessing required	Effective kiln seal difficult to maintain
Existing techniques for the direct disposal of wastes in metal drums	Significant amount of heat lost in ash discharge
	High maintenance required to process inorganic wastes or metal drums in a slagging mode

Table 1, Comparison of Rotary Kiln Advantages and Disadvantages

Particulate carryover in the gas stream is one disadvantage of rotary kilns. At SRS, we burn the combustion gases again in the Secondary Combustion Chamber to ensure complete combustion of the organic materials. Any small particulate that remains unburned is cleaned and separated in the offgas processing and, if micron sized particulate remains after the processing, it is filtered before discharge to the atmosphere.

Selection of the proper rotational speed is an important factor to consider when using rotary kiln incinerators. The residence time of the fuels and streams must be controlled to ensure complete combustion and processing so the flow rate of the materials progressing from the feed head to the discharge head is adequate. If the rotational speed was too fast, incomplete combustion would occur resulting in an excess amount of particulate delivered to the ash handling components. This is unacceptable not only because of volume considerations but also because the products of incomplete combustion (ash and particulate) could still contain high levels of contamination. Incomplete combustion would also cause a higher level of combustible carryover to the secondary combustion chamber and the offgas processing equipment. If rotational speed was too slow the materials would be incinerated long before they traveled the length of the kiln. This would be inefficient because of the amount of auxiliary fuels and combustion air used to sustain the combustion process. Slow speed could also cause unacceptable conditions associated with kiln pressure.

NOTE	One of the observations during PTB was that the speed of the kiln could not be kept slow enough to completely burn some of the solids. During the test of the solid waste feed, unburned pieces of the cardboard boxes containing the solid wastes were found in the ash receiving tank. Another item of note related to kiln speed resulting from PTB testing was the high levels of CO and CO_2 discovered during the solid waste feed. Levels were found to be in the 1500 to 1600 parts per million (ppm) range.

One of the disadvantages of rotary kiln technology is associated with sealing of the kiln. An airtight seal is required to prevent leakage of heat, combustion gases, fuels and contaminants to the atmosphere. Seals also prevent the in-leakage of ambient air into the kiln which could create explosive or unfavorable conditions to complete combustion. As with any rotating assembly, surface contact produces friction which creates heat. Selection of the seal materials must consider this heat generation. Carbon-graphite materials were chosen to allow for malleability of the surfaces, heat resistance and a flow path for cooling and ventilation.

The disposition of the ash and particulates is viewed as both an advantage and disadvantage of rotary kiln technology. Ash handling technology today allows for the safe and efficient immobilization of the contaminated ash (solidification in concrete is used at SRS) but inherent in the treatment process is the high maintenance cost for continued operations.

The table refers to slagging as a process involved in rotary kiln incineration. Slag is defined as a molten or viscous coating produced on refractory materials by ash particles. Slag is usually formed on the refractory walls or materials when they are subjected to high temperatures. Close observation of the rotary kiln internals will reveal slag formations in areas below the burners where fuels have leaked, spilled or not been fully combusted. Slag formations in the refractory require removal during outages because they will prevent design heat transfer, create hot spots and potentially deformation of the refractory and shell of the kiln. As of yet, no slagging has been evident in the CIF kiln.

Summary

- Rotary kiln technology is viable from the aspects of being a proven technology and being able to handle a wide variety of the wastes produced and stored at SRS.
- Incinerator type selection is based upon regulatory, economical, effectiveness, offgas composition, and the generation and handling of secondary wastes
- Rotary kilns tumble the waste solids and control residence times of the combustion gases through the system to ensure complete combustion and particulate cleansing
- Incinerator equipment and components are provided for primary and secondary combustion chambers, waste feed , auxiliary and support systems, and ash or residue processing
- There are advantages and disadvantages inherent in the nature of rotary kiln incineration that must be considered during the design phase and understood and mitigated during the operational phase

Review

1) Complete the following table to explain the reasons for the incinerator selection criteria.

Selection criteria	Reason(s)
Waste feed acceptance	
Process effectiveness	
Offgas composition	
Secondary wastes	
ALARA	

2) Enter the missing information in the table associated with the features, construction and operating characteristics of rotary kiln incinerator types

Feature	Equipment/Construction	Operating characteristics
	Rollers and drive mechanisms	Contact tumbling bed of solids at high temperature with combustion air
Kiln sealing		Prevents escape of gases and contaminants on interface between stationary and rotating sections; seals also use air for pressurization and/or cooling; labyrinth pattern sometimes used
Secondary combustion	Afterburners; two burners (one fuel and one ROW)	
	Combustion air fans	Ensure more than required air available for complete combustion of wastes and fuels; enough air to compensate for losses
Acid gas neutralization		Neutralize pH of combustion gases when burning chlorinated or sulfonated wastes (PVCs, etc.)

2) Complete the following table associated with the components of an incinerator system

Component	Purpose	Design/Construction
Rotary Kiln	primary combustion of fuels and wastes	
	Introduce wastes in controlled manner	Liquid - burners or nozzles Solid - shredded or batched delivery systems
Combustion Air Supply		Forced draft - supply air Induced draft - pull emission gases through filtering system
Auxiliary Heat Supply	Ignite and heat up incinerator to operating temperature for burning wastes	
	Remove residual and particulate matter remaining from burning solid wastes and fuels	Continuous, semi or batch removal Personnel exposure concerns dictate type selected
Secondary Combustion Chamber		Afterburner Sized to ensure residence time (L/D ratio)

4) Identify the advantages associated with a rotary kiln incinerator.

5) Identify the disadvantages associated with a rotary kiln incinerator.

OFFGAS SYSTEMS

Introduction

The incineration of waste materials, regardless of the types, requires the use of air pollution control devices or offgas systems. The ability to properly clean offgas of potentially harmful contaminants is legally required but is also necessary to protect health and the environment and gain public acceptance.

Purpose

1.08	**STATE** the purpose of incinerator offgas treatment.

Offgas systems are used to clean and remove contaminants from the incineration process before emitting the gas stream to the atmosphere. Many different types of systems may be used but several common characteristics for all types are prevalent:

- quenching (cooling)
- scrubbing
- separation
- removal of entrained moisture and contaminants

Offgas Conditioning

1.09	**EXPLAIN** the processing of incinerator offgas to include the components, types of contaminants and the required methods of conditioning for the following: a. Halides (chlorine, fluorine, iodine and bromine) b. Sulfur c. Nitrogen d. Inert materials e. Metals f. Radioisotopes g. Plastic (PVCs)

The conditioning types used in an offgas system include cooling, particulate removal, acid gas removal, humidity adjustment, mist elimination and draft induction (or forced draft). Determination of the type of conditioning to be utilized will be affected by the characteristics of the waste streams in the incinerator. Waste characteristics greatly affect the offgas composition. Characteristics of considerable importance are the concentrations of halides, sulfur, nitrogen, inerts, metals, radioactive isotopes, and plastics. Each of these components contributes to the contaminants of concern in the offgas stream.

Table 2, *Waste Characteristics, Contaminants and Required Conditioning*, shows these elements as well as their constituents/contaminants and applicable conditioning methods.

COMPONENT	CONTAMINANT	CONDITIONING
Halides		Gas scrubbing
Chlorine	HCl, Cl_2	
Fluorine	HF	
Iodine	I_2	
Bromine	Br_2, HBr	
Sulfur	SO_2, SO_3, SOx	Gas scrubbing
Nitrogen	NO, NO_2, NOx	Gas scrubbing
Inerts	Particulate	Filtration
Metals	Particulate Metal Fumes Metal Vapor	Filtration Capture/ Filtration Cooling/ Condensation Adsorption/ Absorption
Radioisotopes	Particulate Fumes Vapor	Ultrafiltration (HEPAs)
Plastics (PVCs)	HCl, Cl_2	Gas scrubbing

Table 2, Waste Characteristics, Contaminants and Required Conditioning

Offgas cooling is performed to decrease the volume and material requirements of the downstream components. A full wet quench (cooling) will typically reduce the volume of the offgas flow by 50% and the temperature to less than 190°F. Cooling can be performed by heat exchange, air dilution and/or wet quench.

Particulate removal is required when the ash content of the waste is such that emissions will exceed applicable regulatory requirements. Particulate removal may be accomplished by using filters, scrubbers and/or electrostatic precipitators. The removal efficiencies vary with type of waste, the diameter of the particulate, and any upstream conditioning.

Gas scrubbing is required when gaseous pollutants are generated by waste incineration. The pollutant most commonly scrubbed is hydrochloric acid (HCl). Sulfur oxides (SOx), nitrous oxides (NOx), chlorides (Cl_2), and others may also be encountered depending upon the waste streams incinerated.

1.10	**DEFINE** the categories of offgas systems to include: a. Wet b. Dry c. Semi-dry/Hybrid

Generally, offgas systems may be grouped into three categories: wet, dry and semi-dry. The categories are defined as follows:

- Wet - a system that uses water, brings the offgas to saturation and discharges to an aqueous waste stream
- Dry - a system that does not use water as part of conditioning
- Semi-dry or Hybrid - a system that uses water but does not bring the offgas to saturation or discharge to an aqueous waste stream

All three categories may be used to accomplish gas conditioning although the effectiveness and advantages vary.

Major Components of Offgas Systems

1.11	**DESCRIBE** the major components of offgas systems including the purpose, design considerations and construction of the following: a. Quencher b. Scrubber c. Cyclone separators d. HEPA filters

Although the types of conditioning and treatment of the offgas streams may vary widely, there are several common components used for most types of conditioning. The components are as follows:

Quench Vessel

The quench is often the first step in the wet offgas system. The purpose of the quench is to cool the offgas temperature down from incineration temperature to saturation temperature (usually less than 190°F) to increase the humidity to saturation and to reduce the volume.

A quench vessel is usually equipped with spray nozzles at a gas inlet to bring the hot gases into contact with water. The nozzles atomize the water to provide rapid evaporation and cooling. The water also forms a film on the sides of the vessel for cooling and corrosion prevention. Excess water is collected at the bottom of the vessel for processing and recirculation. Some quench vessels will add caustic for scrubbing. This process may remove up to 50% of the acids in the offgas.

Scrubbers

A common type of pollution control device used on incinerator offgas systems is a venturi scrubber. At the throat of the venturi, water or caustic is introduced where it is atomized by the high velocity offgas. Gas passes through the throat of the venturi and accelerates to a velocity that fragments the water into a mass of fine droplets creating a scrubbing effect. Downstream from the throat, the cleaned gas decelerates and the water droplets form into a size that is easily separated from the gas stream.

Cyclone Separators

Cyclones remove particulate and water from the offgas by centrifugal separation. Efficiency of the separation depends upon the flow rate always being at or near design optimum conditions. Therefore, cyclones should not be used in system that have large flow variations. Cyclones may be used in both wet and dry applications and may also be operated at high temperatures if they are refractory lined.

HEPA Filters

A HEPA filter is a filter that has a fiber medium for removing particulate and has a design efficiency of at least 99.97% for 0.3 micron particles of dioctylphthalate (DOP). HEPA filtration is normally used only on offgas systems used for processing radioactive waste. HEPA filters are normally protected by prefilters for the removal of dust or moisture.

Wet Offgas System Configuration

1.12	Given the appropriate drawing or block diagram, **LABEL** the major components of a wet offgas system to include the following: a. Quencher b. Scrubber c. Separator d. Demister e. Reheater f. Induced draft fans g. Stack

The most widely used system configuration for offgas conditioning is the wet system. The wet system has both a high particulate removal efficiency and good gaseous scrubbing. A simplified diagram of the CIF offgas system is shown in Figure 4, *CIF Offgas System*.

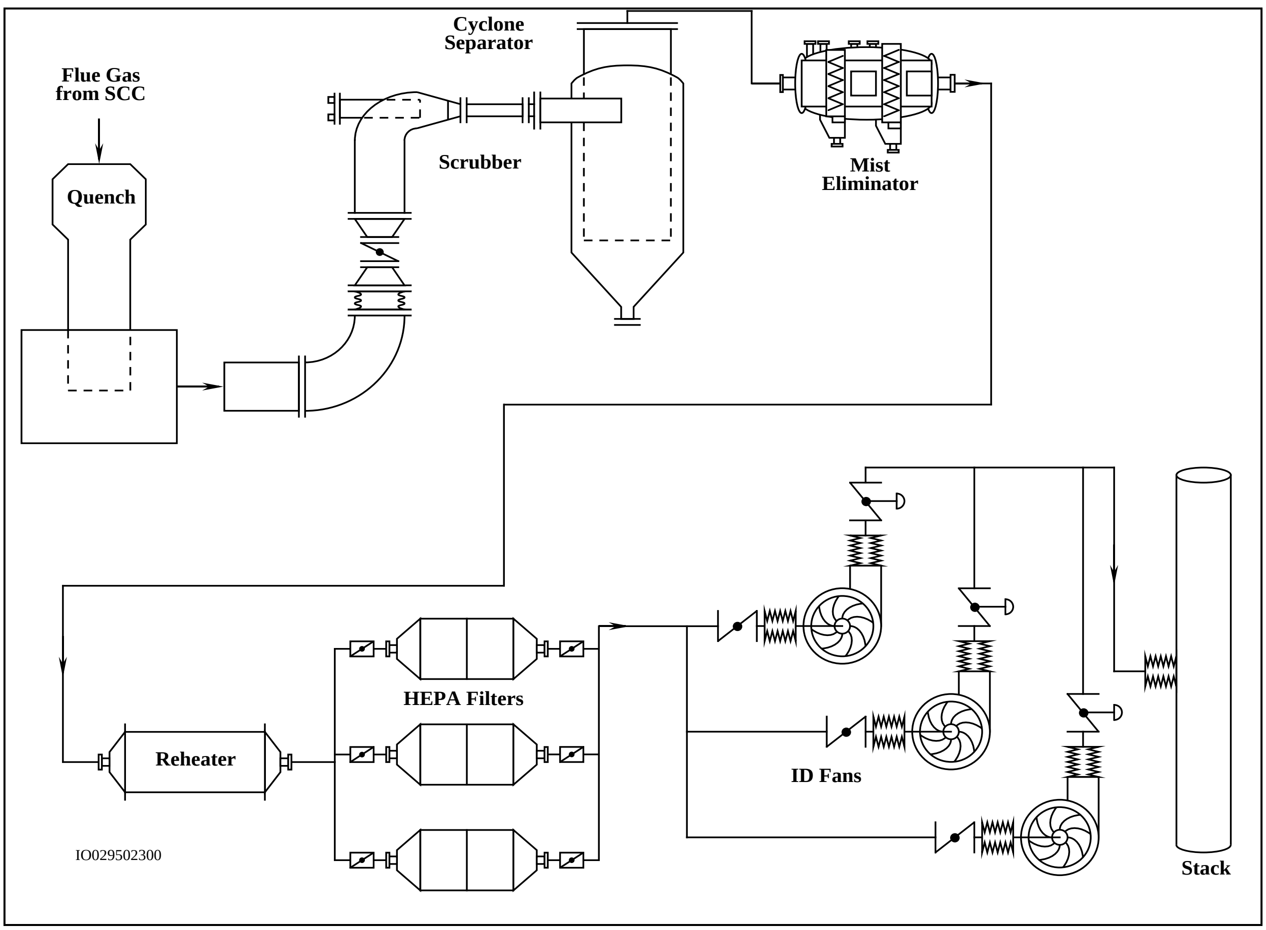

Figure 4, CIF Offgas System

Summary

- Offgas systems are used to clean, filter and remove contaminants from incinerator byproduct gas streams
- There are many types of offgas conditioning. Determination of the type to be used is based upon the characteristics of the wastes and fuels used in the incinerator
- There are three categories that offgas systems may be generally categorized as: wet, dry and semi-dry/hybrid.
- Offgas systems use many unique components for processing

Review

1) Identify the required conditioning of contaminants in incinerator offgas systems by completing the following table.

COMPONENT	CONTAMINANT	CONDITIONING
Halides		
Chlorine	HCl, Cl_2	
Fluorine	HF	
Iodine	I_2	
Bromine	Br_2, HBr	
Sulfur	SO_2, SO_3, SO_x	
Nitrogen	NO, NO_2, NO_x	
Inerts	Particulate	
Metals	Particulate Metal Fumes Metal Vapor	
Radioisotopes	Particulate Fumes Vapor	
Plastics (PVCs)	HCl, Cl_2	

2) What are the differences between the wet, dry and semi-dry/hybrid categories of offgas systems.

3) Complete the following table associated with offgas system components.

Component	Purpose	Design/Construction
Quencher	Cool offgas temperature to saturation	
Scrubber		Venturi for acceleration and mixing
Cyclone separators	Remove water and particulate from offgas stream	
HEPA filters		Prefilters Ultrafiltration 99.97% efficiency

4) Draw a one line diagram of a typical offgas system showing the major components in flow path sequence.

CONSOLIDATED INCINERATOR FACILITY

Introduction

Incineration technology used at the CIF allows for the processing of wastes and fuels. One of the advantages of using rotary kiln technology is that it allows the facility process a wide variety of fuels with many characteristics. At CIF, we incinerate liquid wastes and solid waste using fuel oil and propane for ignition and control. The liquid waste consists of low BTU Aqueous Waste, mid to high BTU Blended Waste, and hazardous Radioactive Organic Waste (ROW). The solid waste consists of a variety of materials with a range of heating values.

The incinerator is used to thermally reduce the volume of wastes at the CIF. Combustion of the waste and fuels is accomplished through feeding the wastes at a controlled rate and in proportion to the amount of air needed to sustain combustion. Steam is also provided for the atomization of the liquid wastes and fuels.

There are numerous auxiliary and support systems used to assist in the incineration process. Electrical power, building ventilation, process water, caustic soda, and plant air a just a few. The following section will discuss the facility systems and how they support the incineration process.

CIF Systems Interrelationships to Incineration

For ease of understanding the incineration process, the facility systems can be grouped into four separate classifications according to functions and purpose:

- Support systems - Air, Water, Nitrogen, Incinerator Fuel Oil, Propane, HVAC, Forced Draft and Purge Air, Fire Protection, Tank Farm Support, Waste Drains and Vents, and Radiation Monitoring
- Electrical systems - Electrical Distribution, Heat Trace, Standby Diesel Generator, and Diesel Fuel Oil
- Process systems - Incinerator, Offgas, Solid Waste, Ash Handling, Liquid Waste
- Integrated systems - DCS, BMS

By using this breakdown, we can group the systems and see how each one within the groups supports the incineration process. This section will address each system in the groupings and show how it assists incineration at CIF.

Support Systems

1.13	**DESCRIBE** the interrelationships of the following support systems to incinerator operation to include the effects on incinerator operation due to a loss of the system. a. Air b. Service Water c. Nitrogen d. RK and SCC Fuel Oil e. Propane f. Forced Draft and Purge Air g. Fire Protection h. Tank Farm Support

Air

The air system has three separate classifications: Plant Air, Instrument Air and Breathing Air.

The Plant Air System is used for the operation of pneumatic equipment such as portable tools and lifts. Plant Air can be used as a backup source for Instrument Air in an emergency since the air sources for both systems are the same compressors. The only difference is the Plant Air System distribution header taps off before the air supply is routed to a dryer.

The Instrument Air System is used for the operation of pneumatic valves, controls and instruments. Because of the usage, instrument air needs to be reliable, dry and oil-free. Instrument Air is used for controllers on the remote and local RK and SCC skids that regulate flows for fuel, waste, steam and air to the incinerator.

Breathing Air is used for personnel access to contaminated or hazardous areas. Normally, personnel will only require Breathing Air when the incinerator is shut down because access to contaminated areas is not desirable during normal operations.

Loss of the Instrument Air System will prevent or hinder operation of the incinerator pneumatic controls and instruments which leads to either operating at reduced capacities or shutdown.

Service Water

Water is used in the facility for many process needs. Water is used for makeup to the Ash Receiving Tank to ensure that the ash residue from combustion can be quenched, immobilized and stored. Water is also used for cooling makeup to the Offgas System and dilution of the Aqueous Waste Storage Tank. Water is also used throughout the facility for heat exchanger cooling.

Loss of the Service Water System would result in a shutdown because of the inability to provide equipment cooling and makeup for the ash and offgas processing.

Nitrogen

There are two separate Nitrogen Systems used for two extremely important purposes. In the Tank Farm, nitrogen is used as an inert blanket on the waste storage to ensure that the air is displaced thereby preventing the possibility of exothermic reactions with the liquid wastes. Nitrogen is also used for fire suppression in the Ram Feed Housing of the Solid Waste Feed System. If a flame were to ignite the solid waste in the housing, the nitrogen would extinguish the fire by displacing the oxygen.

A loss of the Nitrogen System would require an incinerator shutdown because of the loss of the inert blanketing on the liquid waste storage tanks and the concern with exothermic reactions. A loss of the Nitrogen Fire Suppression System would require a shutdown of the solid waste feed to the incinerator because of the concern with a fire in the feed system housings.

RK and SCC Fuel Oil

Incinerator fuel oil is used to control the primary process parameter, temperature, in the incineration process. Because of it's High Heating Value (HHV), a relatively small adjustment in the flow of fuel oil can cause a significant change in the temperature in a smaller time span that the waste materials.

A loss of the Fuel Oil System would cause an incinerator shutdown because of the inability to control the temperature with the waste feeds.

Propane

Propane is used for the initial ignition of the incinerator burners.

A loss of the Propane System would prevent starting the incinerator from a standby condition or lighting additional burners during a warmup. A loss of the Propane System would not require a shutdown if the incinerator was operating but it would prevent the initial light off of additional burners.

HVAC

The building ventilation is controlled by the HVAC System to create pressure boundaries. This causes the incinerator to have a lower pressure than the surrounding areas thereby ensuring that any spread of gases of vapors will be directed into, rather than out of, the incinerator.

A loss of the facility HVAC System would create a potential for release of contaminants. The incinerator would require shutdown in the event of a loss of the HVAC System pressure boundaries to prevent the release of contaminants to the environment.

Forced Draft and Purge Air

The forced draft fans supply the combustion and cooling air for the fuels, wastes, seals, and instrumentation on the RK and SCC. The Purge Air System prevents the accumulation of combustible or contaminated gases and vapors in the Solid Waste Feed housings and the RK seal shrouds.

A loss of the forced draft fans would prevent the efficient combustion of the wastes and fuels in the incinerator. A loss of any waste stream combustion air would require the cutoff of that waste feed and adjustments to the other wastes and fuels to maintain incinerator temperature.

Fire Protection

The Fire Protection System provides suppression and detection of fires throughout the facility.

Loss of the Fire Protection or Detection Systems would significantly hinder the continued safe operation of the incinerator but would not require a shutdown.

Tank Farm Support

The Tank Farm Support Systems provide storage and mixing (Spare Tank), testing (Automatic Sampler), and unloading (Rad Oils/Solvents) capability for the liquid wastes at the Tank Farm.

Loss of the Tank Farm support systems would not require a shutdown as long as storage capability was not hindered.

Electrical Systems

1.14	**DESCRIBE** the interrelationships of the following electrical systems to incinerator operation to include the effects on incinerator operation due to a loss of the system. a. Electrical Distribution b. Heat Tracing c. Standby Diesel Generator d. Diesel Fuel Oil

Electrical Distribution

The Electrical Distribution System provides all the facility required power for electrical loads. All of the pumps and fans associated with the Incinerator run off of electrical power. The system also includes the Uninterruptable Power Supply (UPS) which provides power to the DCS, some instrumentation and the Monitoring Systems should normal facility power be lost.

Loss of the Electrical Distribution System would cause an incinerator shutdown because of the loss of power to electrically-powered equipment and components.

Heat Trace

The system prevents process water and liquid lines from freezing in the event of cold and freezing temperatures.

A loss of the Heat Trace System would not affect incinerator operations unless the ambient conditions required heat tracing to be in service for operation of controls, instruments, equipment, piping or components.

Standby Diesel Generator

The system provides an alternate source of power in the event of a loss of the normal supply. Two of the 480 Volt load centers have required equipment that will be powered from the diesels to ensure that the incinerator and the facility may be safely shut down.

A loss of one standby diesel generator would not require incinerator shutdown because the facility is equipped with a backup. The facility is restricted from normal operation with only one diesel generator available for service.

Diesel Fuel Oil

The system provides a source of fuel for the Standby Diesel Generators.

The loss of the Diesel Fuel Oil System affect on facility operation would parallel that of the loss of the standby diesel generator(s). That is, if only one fuel supply to one diesel generator was lost, the facility operation would be possible but the operating mode would be restricted.

Process Systems

1.15	**DESCRIBE** the interrelationships of the following process systems to incinerator operation to include the effects on incinerator operation due to a loss of the system. a. Incinerator b. Offgas c. Solid Waste d. Ash Handling e. Liquid Waste

Incinerator

Thermally destroys and reduces the waste materials characterized as suitable for incineration.

Offgas

Processes the incinerator exit gases to ensure they are free from contaminants and within the permit requirements for stack emissions to the atmosphere.

A loss of the Offgas System would require an incinerator shutdown because of the inability to clean and process the combustion gases generated from incineration.

Solid Waste

Processes and delivers batches of pre-packaged waste materials for incineration. System will also survey and document test results for trending and history file.

A loss of the Solid Waste Feed System would not require incinerator shutdown. If the system was lost while the incinerator was being fed solid waste, the other wastes and fuels would be adjusted to maintain incinerator temperature.

Ash Handling

Processes the ash and solids residue from incineration into an immobilized form suitable for long or short-term storage and disposition.

A loss of the Ash Handling System while burning solid waste would require an incinerator shutdown within twenty-four hours because of the inability to process the residue from the solids.

Liquid Waste

Stores, mixes and transports the liquids for incineration.

A loss of a liquid waste feed would shutdown that particular burner/nozzle and require the other wastes and fuels to be adjusted to maintain temperature.

<u>Integrated Systems</u>

1.16	**DESCRIBE** the interrelationships of the following integrated systems to incinerator operation to include the effects on incinerator operation due to a loss of the system. a. DCS b. BMS

DCS

Controls and monitors processes that are occurring in the CIF.

A loss of the DCS would cause an incinerator shutdown because of the loss of control and monitoring ability.

BMS

Safeguard system for incinerator burners, fans and controls to ensure safe and efficient operation of the combustion process.

A loss of the BMS would shut down the incinerator because of the loss of safeguards and controls associated with incinerator operation.

Incinerator Waste Streams and Fuels

1.17	Given applicable references and a scenario with operating parameters for incinerator fuels and wastes, **DETERMINE** if the values are credible and within design limits for the following fuels and wastes: a. Solid Waste b. Liquid Waste c. Aqueous Waste d. Fuel Oil e. Radioactive Organic Waste (ROW)

The waste and fuel characteristics are important to consider when operating the incinerator. The operating personnel must have a fundamental understanding of the characteristics of the constituents of the incinerator fuels to ensure controlled and regulated operation of the process. Table 3, *CIF Fuel Characteristics*, identifies the fuels and waste streams, their constituents and their heat values.

FUEL/ WASTE	MAX. FLOW (LB/HR)	AVG HEAT VALUE (BTU/LB)	CONTENTS	WEIGHT %	HIGH HEAT VALUE (BTU/LB)
			R K		
Solid Waste	900 *	4,765			
			Cellulose	40	8,000
			Polyvinyl Chloride (PVCs)	8	11,400
			Polyethylene	23	20,000
			Latex (Polyisoprene)	19	19,000
			Water	5	0
			Ash	5	0
Liquid Waste	385	17,951			
			Tritiated Oil	22.6	18,500
			Purex Solvent	3.4	18,400
			Naval Fuel	9.8	13,400
			High BTU NRHW	44.8	18,850
			Chlorinated NRHW	2.1	9,900
			Fuel Oil Flush	17.2	18,400
Aqueous Waste	950	2,200	Aqueous NRHW	0.1	2,200
Fuel Oil	543	19,200			
			S C C		
Rad. Organics	191	18,000			
			Benzene	90.8	*a
			Biphenyl	4.95	*a
			Diphenylamine	3.37	*a
			Phenol	0.73	*a
			Phenylboric Acid	0.06	*a
			p-Terphenyl	0.07	*a
			Diphenyl Mercury	0.03	*a
			Chlorobenzene	0.02	*a
Fuel Oil	462	19,200			

Table 3, CIF Fuel Characteristics

* Minimum 90% combustible
*a Average HHV is 18,400 BTU/lb

It is important to understand the difference between the terms terms High Heating Value (HHV) and Low Heating Value (LHV) when looking at the waste materials. The determination of the heat of combustion of waste materials to be incinerated is an important design consideration. The heat of combustion, represented by the symbol ΔH_c, simply means the asmount of heat liberated by one pound of waste material when it is combusted. Heat of combustion is shown in units of BTU/lb. Depending upon the labratory procedure used to calculate waste material heat of combustion, the units HHV or LHV may be used. The difference between the values is that the HHV accounts for any latent heat of condensation of the combusting materials. The latent heat of condensation is the amount of heat given up when water undergoes a phase change from gaseous steam to liquid. The LHV does not account for this. The following two equations demonstrate the difference.

HHV - CH_4 (gaseous) + $2O_2$ (gaseous) = CO_2 (gaseous) + $2H_2O$ (liquid)

LHV - CH_4 (gaseous) + $2O_2$ (gaseous) = CO_2 (gaseous) + $2H_2O$ (gaseous)

As seen in the equation, the LHV shows the water remaining in a gaseous form and does not account for any condensation. At CIF, as throughout most of the United States, the HHV of waste materials is normally used.

<u>Summary</u>

- The rotary kiln incinerator at CIF thermally destroys wastes
- Facility systems can be classified as being process, support, electrical or integrated Operations for the purpose of viewing the system interrelationships to incinerator operation
- Fuels and waste characteristics are important to consider when operating the incinerator

Review

1) Identify the effects on continued incinerator operation in the event of a loss of the Electrical Distribution System.

2) Identify the effects on continued incinerator operation in the event of a loss of the Burner Management System.

3) Calculate if the facility is operating within the permit limits for the following waste flows (assume nominal heating values for all fuels and wastes).

RK Fuel Oil - 266 lbm/hr
RK Aqueous Waste - 900 lbm/hr
RK Liquid Waste - 250 lbm/hr

SCC Fuel Oil - 450 lbm/hr
SCC ROW - 110 lbm/hr

4) Calculate if the facility is operating within the permit limits for the following waste flows (assume nominal heating values for all fuels and wastes).

RK Fuel Oil - 175 lbm/hr
RK Aqueous Waste - 600 lbm/hr
RK Liquid Waste - 400 lbm/hr

SCC Fuel Oil - 350 lbm/hr
SCC ROW - 180 lbm/hr